Welding Consumables for Power Plants

Power Plants

- An industrial facility used to generate electric power with the help of one or more generators which converts different energy sources into electric power.
- Electricity is a secondary energy source, which means that electricity is obtained from the conversion of other primary sources of energy, such as coal, natural gas, nuclear, solar, or wind energy.
- The energy sources used to make electricity can be renewable or non-renewable, but electricity itself is either renewable or non-renewable.

Power Plants

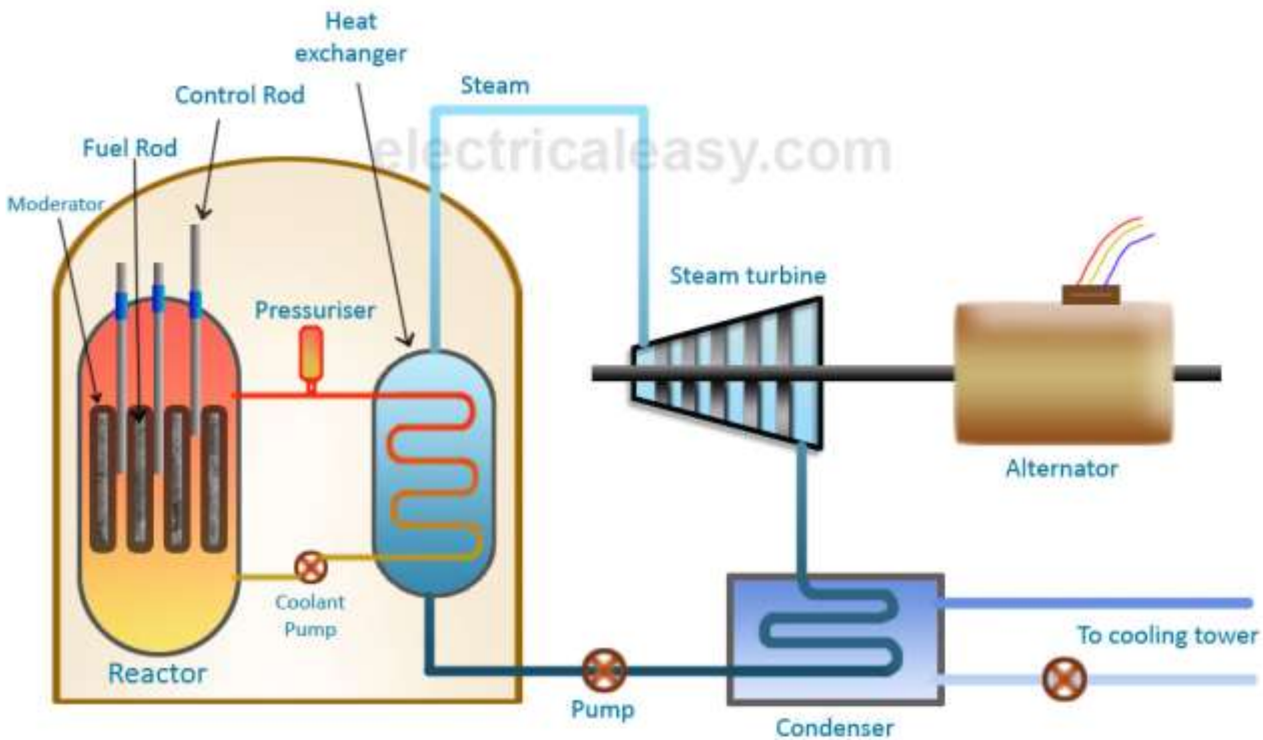
- Conventional power plants are:
  - Fossil fuel power plants: Generates electric power by burning fossil fuels like coal, natural gas or diesel.
  - Nuclear power plants: Controlled nuclear reaction is maintained to generate electricity.
  - Hydroelectric power plants: Electricity is produced by building dams on suitable rivers.
- Non-conventional power plants are:
  - Wind power plants: The kinetic energy of wind is used to create power.
  - Solar power plants: Generates power by collecting solar radiation.
  - Geothermal power plants: Uses the natural heat found in the deep levels of the earth to generate electricity.
  - Biomass power plants: Natural organic matter is burnt to produce electricity.

Power Plants

- Thermal Power Plant
- Nuclear Power Plant
- Wind Power Plant
- Hydroelectric Power Plants

Nuclear Power Plant

Basic Plant Layout



Working of Nuclear Power Plant

- In a **nuclear power plant**, heat energy is generated by a nuclear reaction called as **nuclear fission**.
- Nuclear fission of heavy elements such as Uranium or Thorium is carried out in a special apparatus called as a **nuclear reactor**.
- A large amount of heat energy is generated due to nuclear fission.
- Rest parts of a nuclear power plant are very similar to conventional thermal power plants.
- It is found that fission of only 1 Kg of Uranium produces as much heat energy as that can be produced by 4,500 tons of high grade coal. This considerably reduces the transportation cost of fuel, which is a major **advantage of nuclear power plants**.
- Also, there are large deposits of nuclear fuels available all over the world and, hence, nuclear power plants can ensure continued supply of electrical energy for thousands of years. About 10% of the total electricity of the world is generated in nuclear power plants.

Working of Nuclear Power Plant

- Heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission reaction in a nuclear reactor.
- Due to fission, a large amount of heat energy is produced which is transferred to the reactor coolant.
- The coolant may be water, gas or a liquid metal.
- The heated coolant is made to flow through a heat exchanger where water is converted into high-temperature steam.
- The generated steam is then allowed to drive a steam turbine. The steam, after doing its work, is converted back into the water and recycled to the heat exchanger.
- The steam turbine is coupled to an alternator which generates electricity.
- The generated electrical voltage is then stepped up using a transformer for the purpose of long distance transmission.

Basic Components

- Nuclear Reactor –
  - A nuclear reactor is a special apparatus used to perform nuclear fission. Since the nuclear fission is radioactive, the reactor is covered by a protective shield.
  - Splitting up of nuclei of heavy atoms is called as nuclear fission, during which huge amount of energy is released.
  - Nuclear fission is done by bombarding slow moving neutrons on the nuclei of heavy element.
  - As the nuclei break up, it releases energy as well as more neutrons which further cause fission of neighbouring atoms. Hence, it is a chain reaction and it must be controlled, otherwise it may result in explosion.
  - A nuclear reactor consists of fuel rods, control rods and moderator.
  - A fuel rod contains small round fuel pallets (uranium pallets).
  - Control rods are of cadmium which absorb neutrons. They are inserted into reactor and can be moved in or out to control the reaction. The moderator can be graphite rods or the coolant itself.
  - Moderator slows down the neutrons before they bombard on the fuel rods.

Basic Components

Two types of nuclear reactors that are widely used –

- **Pressurised Water Reactor (PWR)** -
  This type of reactor uses regular water as coolant. The coolant (water) is kept at very high pressure so that it does not boil. The heated water is transferred through heat exchanger where water from secondary coolant loop is converted into steam.

- **Boiling Water Reactor (BWR)** -
  In this type of reactor only one coolant loop is present. The water is allowed to boil in the reactor. The steam is generated as it heads out of the reactor and then flows through the steam turbine.

Basic Components

- **Heat Exchanger**
  - In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. Heat exchanger is absent in boiling water reactors.
- **Steam Turbine**
  - Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.
- **Alternator**
  - The steam turbine rotates the shaft of an alternator thus generating electrical energy. Electrical output of the alternator is the delivered to a step up transformer to transfer it over distances.
- **Condenser**
  - The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

Nuclear Power Plants – Material Used

- Creep resistant steels alloyed with Chromium, Molybdenum, vanadium, offer improved oxidation and corrosion resistant. They are used widely in nuclear power plants.
- Stainless steels are used extensively in the construction of nuclear power plants, primarily for their corrosion resistance. Core and secondary parts of most reactor types in service today, including pressurized water reactors, boiling water reactors, advanced gas-cooled reactors, and fast breeder reactors, are built from stainless steel, as are reprocessing plants and research reactors. The nuclear decommissioning and waste storage industry is also a prime user of high-quality stainless for different types of transport or storage canisters and boxes for low- to high-level waste.
- ASME Section III details the requirements of Safety related components in nuclear power plants.

Nuclear Power Plants – Material Used

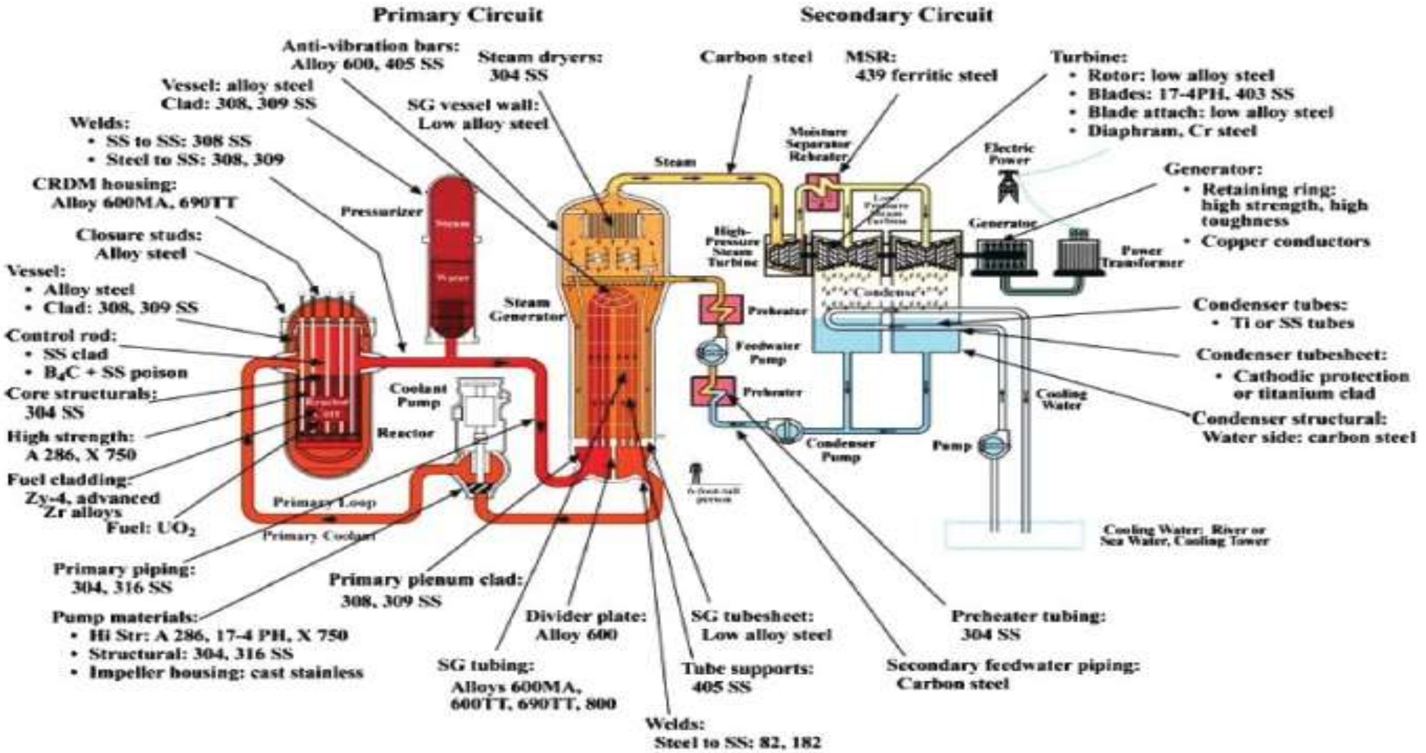


Figure 2 – Typical structural materials in use in a modern PWR (Zinkle and Was, 2013)

Welding Consumables for Creep resistant steels

S.No.	Alloy Group	ASME Sec II Part C
1	0.5 Mo	E7018-A1, ER70S-A1, EA2, EA3, EA4, Basic SAW Flux
2	1.25Cr-0.5Mo (P11)	E8018-B2, E8015-B2, E8016-B2, ER80S-B2, E81T-1B2, EB2, EB2R, Basic SAW Flux
3	1Cr-1Mo-V	E9018-G, ER90SG
4	2.25Cr-1Mo (P22)	E9018-B3, E9016-B3, E9015-B3, ER90S-B3, E91T-1B3, EB3, EB3R, Basic SAW Flux
5	2.25Cr-0.5Mo-2W-V-Nb-B (T23)	E9015-B23, E9016-B23, E9018-B23, EB23, Basic SAW Flux
6	2.25Cr-1Mo-V-Nb (T24)	E9015-B24, E9016-B24, E9018-B24, EB24, Basic SAW Flux
7	9Cr-1Mo-V-Nb (P91)	E9015-B91, E9016-B91, E9018-B91, ER90S-B9, E91T-1B9, EB91, Basic SAW Flux
8	9Cr-0.5Mo-1.5W-V, Nb (P92)	E9015-B92, E9016-B92, E9018-B92

Chemical Composition

S.N.	Weld Metal	C	Mn	Cr	Mo	Others
1	A	0.12	0.60	--	0.40-0.65	--
2	B2	0.05-0.12	0.90	1.00-1.50	0.40-0.65	--
3	B3	0.05-0.12	0.90	2.00-2.50	0.00-1.20	--

Chemical Composition

SN	Weld	C	Mn	Cr	Mo	V	Nb	Al	Others
4	B23	0.04- 0.12	1.00	1.9- 2.9	0.30	0.15- 0.30	0.02- 0.10	0.04	W-1.5-2 B-0.006 Cu-0.25 N-0.05
5	B24	0.04- 0.12	1.00	1.9- 2.9	0.80- 1.20	0.15- 0.30	0.02- 0.10	0.04	Ti-0.10 B-0.006 Cu-0.25 N-0.07
6	B91	0.08- 0.13	1.20	8.0- 10.5	0.85- 1.20	0.15- 0.30	0.02- 0.10	0.04	Ni-0.80 Cu-0.25 N-0.02-0.07
7	B92	0.08- 0.15	1.20	8.0- 10.0	0.30- 0.70	0.15- 0.30	0.02- 0.08	0.04	Ni-1.00 W-1.5-2 Cu-0.25 B-0.006 N-0.03-0.08

Welding Consumables for Creep resistant steels

S.No.	Weld Metal	Alloying	Preheat / Interpass Temperature (°C)	PWHT Temperature (°C)
1	A	0.5 Mo	95-110	620
2	B2	1.25 Cr - 0.50Mo	160-190	690
3	B3	2.25Cr - 1Mo	160-190	690
4	B23	2.25Cr-0.5Mo-2W-V-Nb-B	180-250	740
5	B24	2.25Cr-1Mo-V-Nb	180-250	740
6	B91	9Cr-1Mo-V-Nb (P91)	200-315	760
7	B92	9Cr-0.5Mo-1.5W-V, Nb	200-315	760

Mechanical Properties requirements

S. No.	Weld Metal	UTS (Mpa) Min	YS Mpa Min	Elongation % (4d)
1	A	490	390	22
2	B2	550	460	19
3	B3	620	530	17
4	B23	620	530	17
5	B24	620	530	17
6	B91	620	530	17
7	B92	620	530	17

Effect of PWHT Temperature on YS of weld metal

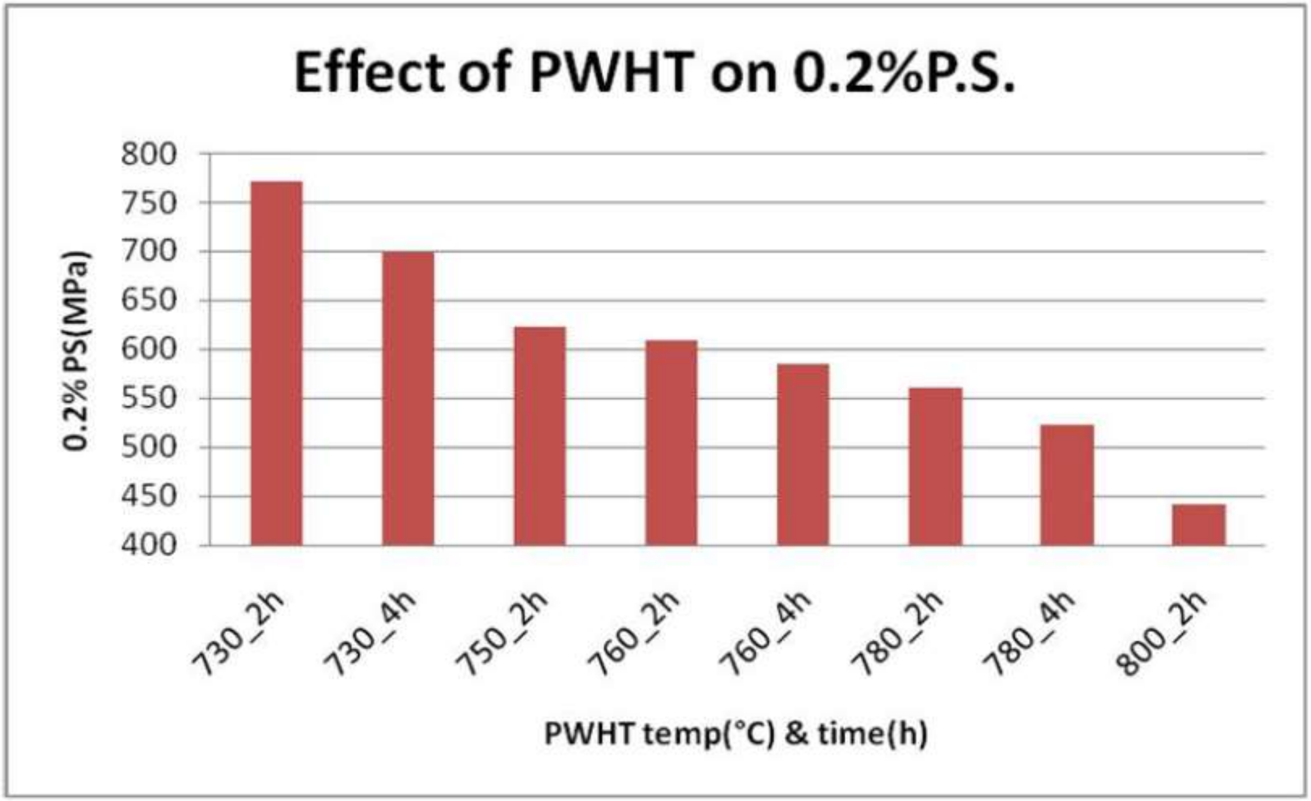


Figure 4.23 Effect of PWHT temperature and time on yield strength

Additional Requirements

- Diffusible Hydrogen
- Impact at -30 / -20°C for B2 & B3
- X Factor – Bruscato Factor – 15 max / 12 max
- Creep Properties – Creep rupture strength / Creep data for 1000 Hrs / 10000Hrs
- Step Cooling Heat treatment – For assessment of Temper Embrittlement
- Mn+Ni < 1.40 in B91

Bruscato X Factor

- The Bruscato X-factor is a way to measure temper embrittlement resistance in applications where the weld metal deposit may be exposed to high temperatures over a long period of time. Certain residual elements (Phosphorus, Tin, Antimony, and Arsenic) migrate to grain boundaries over time in these high temperature conditions, causing a loss of toughness. This is known as temper embrittlement.
- The X-factor is a numerical value that is calculated based on levels of residual elements in the weld deposit – lower x-factors represent lower levels of these tramp elements and higher resistance to temper embrittlement.

Bruscato X Factor

- It is especially important to know the X-factor when welding certain chrome-moly steels, such as those used for boilers, process piping, steam tubes, heat exchangers, pressure vessels, and similar applications that are subject to high service temperatures for extended periods of time. Typical grades of chrome-moly steel for which the X-factor is most relevant include ASTM A387 grades, for example, 11, 21, 22, and 91. Many customer specifications in the pressure vessel and petrochemical industry call for E8018-B2 or E9018-B3 electrodes with an X-factor of less than 15.

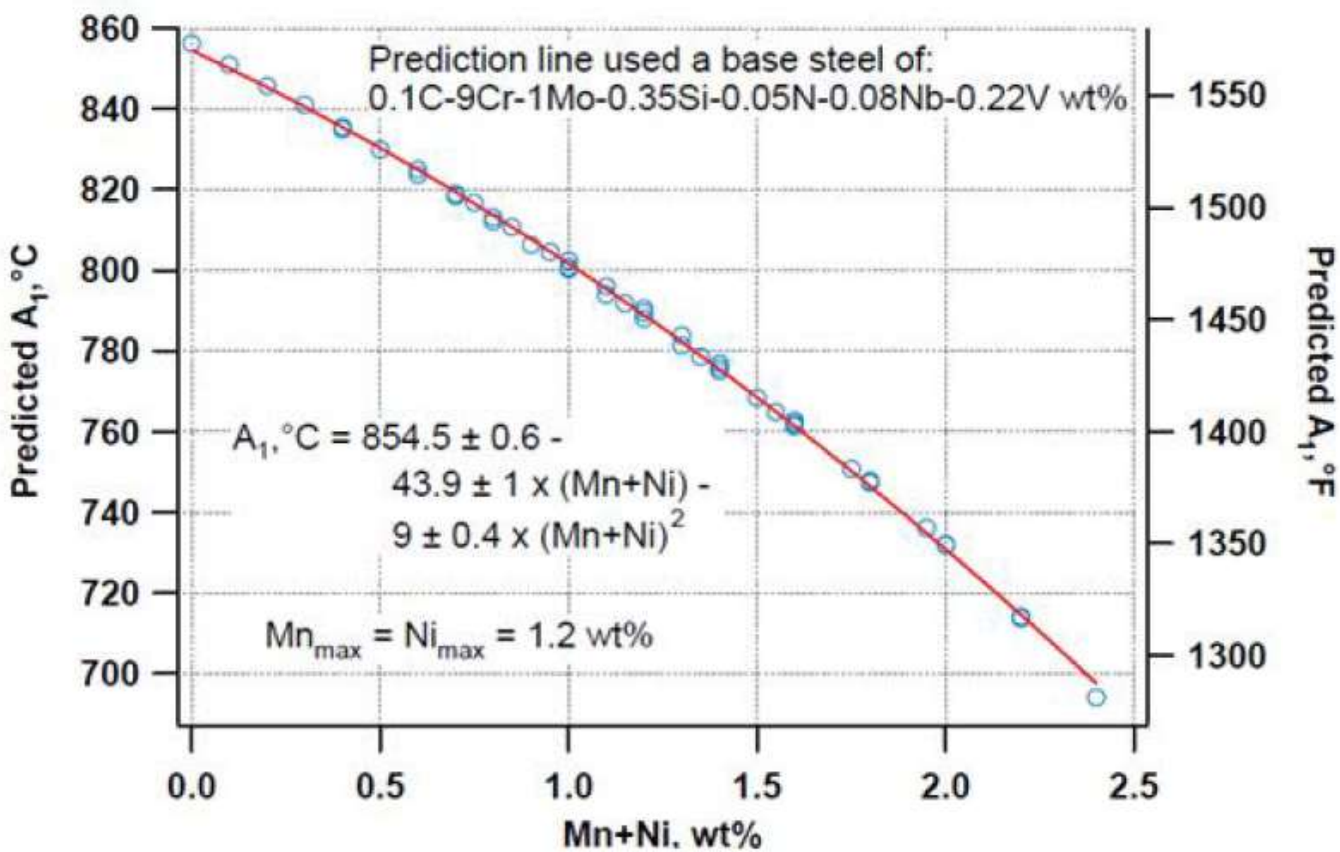
The X-factor Formula

$$X = (10P + 5Sb + 4Sn + As)/100$$

Mn & Ni requirements

- The maximum allowable temperature for postweld heat treatment is also critical in that the lower transformation temperature (*Ac*1) is also comparably low.
- To aid in allowing for an adequate postweld heat treatment, the restriction on Mn +Ni has been imposed
- The combination of Mn and Ni tends to lower the *Ac*1 temperature to the point where the PWHT temperature approaches the *Ac*1, possibly causing partial transformation of the microstructure.
- By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the *Ac*1 to avoid this partial transformation.

Mn + Ni requirements



Step Cooling Heat Treatment for B3

Temperature (°C)	Holding Time (Hour)	Cooling Rate to the Next Temperature(°C per Hour)
595	1	6
535	15	6
525	24	6
495	60	3
470	100	28
315		Air cool

Step Cooling Heat Treatment for B3

11) Impact tests of each Step Cool Test sample shall be performed and transition curves developed per the requirements of Section 6 .above.

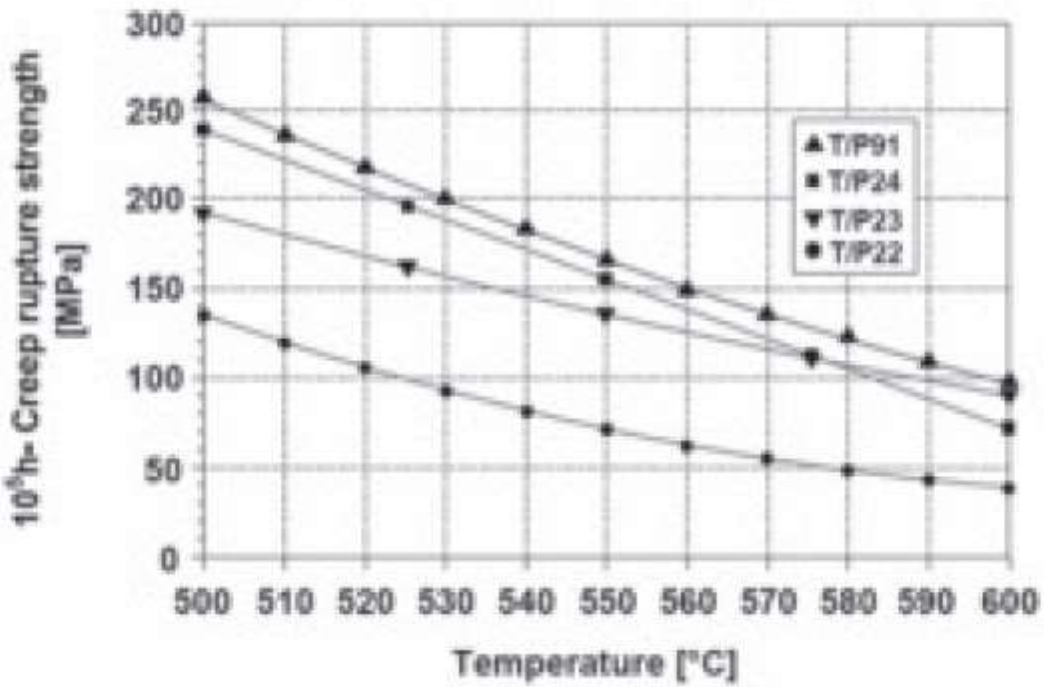
12) Acceptance criteria for the material shall be in accordance with the following:

$$CvTr40 + 2.5\ \Delta CvTr40sc \leq 10^{\circ}C$$

Where

CvTr40	=	Charpy V-notch 55 Joules impact energy transition temperature of completely heat treated specimens before step cooling.
ΔCvTr40 SC	=	The shift in the Charpy V-notch 55 Joules impact energy transition temperature after step cooling

Comparative Creep Strength



Welding Consumables for Stainless Steels

S.N.	Base Metal	Welding Consumable
1	304H	E308L, E308H
2	310	E310
3	316L	E316L
4	316LN	E316L (Modified)
5	904L	E385
6	Dissimilar Welds	E309 / E309L

Welding Consumables for Ni Based Material

S.N.	Base Metal	Welding Consumable
1	Alloy 617	EniCrCoMo-1
2	Alloy 625	ENiCrMo3
3	Alloy C22	ENiCrMo-10
4	Alloy C276	ENiCrMo4
5	9% Nickel	ENiCrMo4 / ENiCrMo3
6	Dissimilar	ENiCrFe2, ENiCrFe3, ERNiCr-3

Welding Consumables for Repair and Maintenance

Sr.No.	Application	Base Metal	Wear / Damage	Products
1.	Crusher Hammer	Manganese Steel	Abrasion	12%/16% Mn Steel + 550BHN Weld
2.	Wagon Tippler Gear	Cast Steel	Friction	E7016 + 250/350BHN Weld
3.	Pump Housing / Bell Housing	Cast Iron	Friction	ENiFe-CI / ENiCI
4.	Coal Mill Pulveriser Pinion	Steel	Abrasion	E7016 + 550BHN Weld
5.	I.D. Fan Blades	Mild Steel	Erosion	High C-Cr alloy 600BHN
6.	Coal Pipe Bends	Carbon Steel	Abrasion	E7016 + 550BHN Weld
7.	Coal Burner Tips	Stainless Steel	Heat + Erosion	E310

Welding Consumables for Repair and Maintenance

Sr.No.	Application	Base Metal	Wear / Damage	Products
9.	Coal Ash Grinder	Mn Steel	Abrasion	12% Mn Steel + 550BHN Weld
10.	Butterfly Valves	Cast Iron	Erosion	ENiFe-CI / ENiCI
11.	Water Pump Body	Cast Iron	Erosion	ENiFe-CI / ENiCI
12.	Diffuse Water Pump	Cast Iron	Erosion	ENiFe-CI / ENiCI
13.	Impeller Water Pump	stainless Steel	Erosion	E410
14.	Turbine Housing	Steel	Breakage	E7016 / E312
15.	Turbine Blade	Stainless Steel	Erosion	E410

Welding Consumables for Repair and Maintenance

Sr.No.	Application	Base Metal	Wear / Damage	Products
16.	Turbine Diaphragm	Stainless Steel	Heat and Abrasion	E310
17.	Turbine rotor shaft	Alloy Steel	Sheared	E312
18.	Pump impeller	Stainless Steel	Marks	E312
19.	Girth gear of the bowl mill	Cast Steel	Abrasion	E7016 + 350BHN Weld
20.	Springs	Spring Steel	Breakage	Not recommended to weld. Can try with E312.
21.	Clinker-grinder	Manganese Steel	Abrasion	12Mn Weld + High C-Cr Weld
22.	Isolating valves / Butterfly valves	Cast Iron	Breakage	ENiFe-CI / ENiCI

Welding Consumables for Repair and Maintenance

Sr.No.	Application	Base Metal	Wear / Damage	Products
23.	Generator Exciter coupling	Alloy Steel	Breakage	E312
24.	Screen bars	Manganese Steel	Breakage	Mn Austenitic weld
25.	Multistage cyclone re-circulating fan blade	Steel	Wear	E7016 + 550BHN weld

Thank You….!